Technology Evolution in Vegetables

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Biotechnology has played an important role in driving new products for agriculture, and has changed the way growers think about controlling insects, for example As head of our field organization, I spend a lot of time with growers and see firsthand the advantages of modern technologies, and, as a scientist, I get of a lot of satisfaction out of that. We should think of this infusion of biology—driving agricultural innovation over the last 25, 30, 40 years—in a much broader sense.

Innovative Technologies for Agriculture

Transgenic technology was the first generation in using modern biology to improve agriculture and bring novel products to the marketplace. This has also driven innovation in terms of how we think about breeding, and how we think about trait associations, and delivery of new traits to the marketplace, whether it be through transgenics or through advanced breeding technologies. It's now playing out, for us and for other players, in a new sector that we call "Ag Biologicals" (Figure 1). The more we understand about basic biological processes—the more we understand at the genetic level—we can begin to think in terms of transforming the biological sector with very innovative technologies.

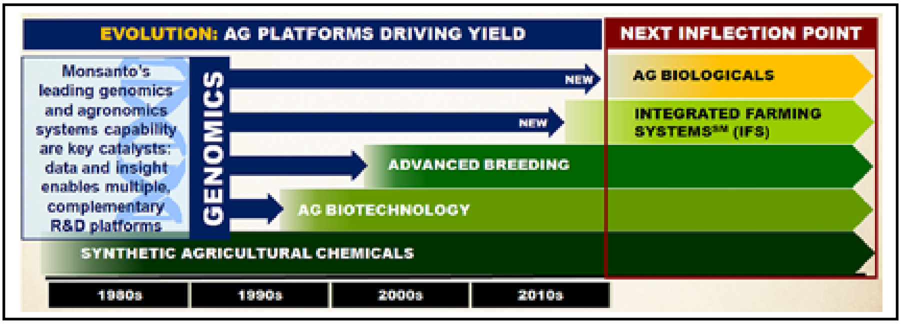

Figure 1. Bringing genomics to the field with integrated farming systems and agricultural biologicals.

We think about genomics in terms of the ability to understand, at a genetic level, how traits play out. It's a key piece of advanced breeding methodology and we see it also as a key piece in understanding how to drive value in the Ag Biologicals sector.

I had the pleasure of heading Monsanto's insect-control program in the 1990s, when we were developing YieldGard® and Bollgard® and did the first work on corn rootworm. Seeing the impact that these technologies have had at the grower level has been tremendously satisfying, particularly in terms of reductions in insecticide-spraying (Figure 2). Growers were applying insecticides to sweet corn up to 20 times in a season. In the southeast some had to spray daily or even twice a day in order to prevent visible damage.

Sweet Corn

For sweet corn, the acceptable level of insect control is the absence of worms when the ear is opened. There is very little tolerance for damage to the ear, which is why heavy spray regimes were necessary. Tony Shelton's data[1] backs this up as well. Clearly, this situation is tailor-made for *Bt* technology (Figure 2). The reduced damage that the retail sector is looking for is achievable. It's a tremendous advantage with transgenic technology. On the other hand, the advantage is difficult to talk about at a consumer level because most people don't think about how often sweet-corn crops are sprayed before they reach the marketplace.

There's been a lot of discussion at this conference on the regulatory system and costs of achieving deregulation. One advantage of this transgenic technology is that the event we

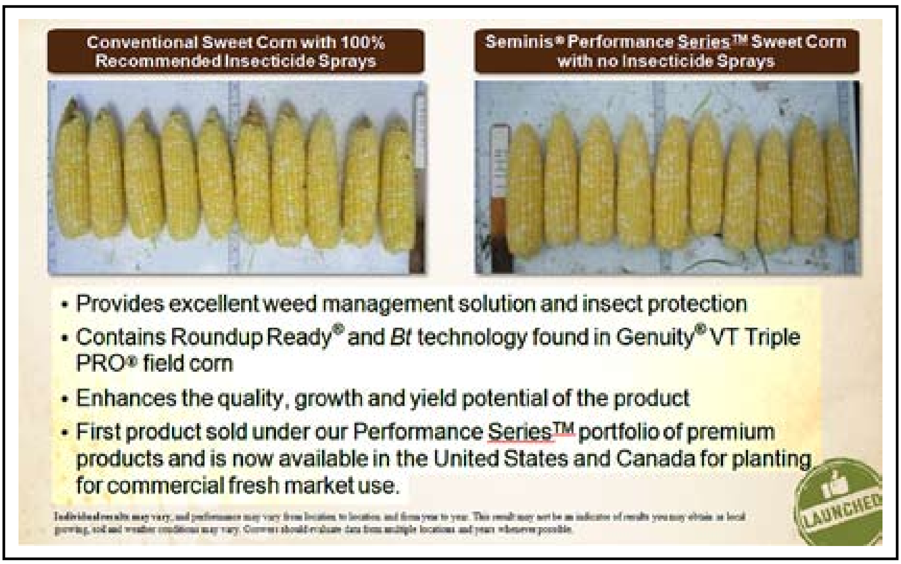

Figure 2. Biotechnology: Seminis® Performance Series™ sweet corn provides protection against insect predation.

[1]Pages 49–58.

used in sweet corn was the same as that in field corn. When the event has been previously approved, fewer steps lie ahead in the deregulation process. This helped us to justify the cost of deregulation in terms of the market size we were going into. This has been launched in the United States at the grower level. Some challenges occurred at the retail level, but it is now actually working pretty well for us. The overall benefits of this technology make it very advantageous. The other product we have in the marketplace—created using a transgenic technology—is virus-resistant squash. It's been available for a number of years. Again, it has grower advantages from a productivity standpoint.

Advanced Breeding Techniques

Our major play in vegetables is to take advantage of advanced breeding techniques, which entail the ability to associate, at the genetic level, from a trait perspective back to a molecular marker which allows our breeders to be more efficient in making selections (Figure 3).

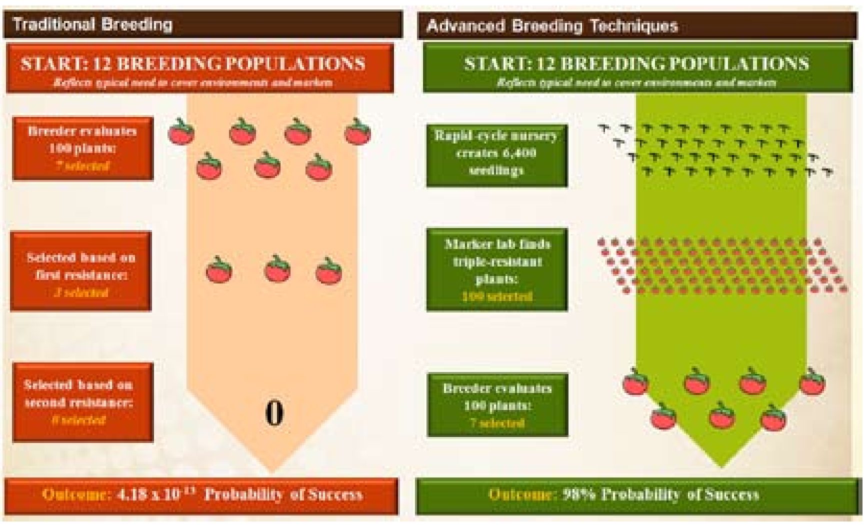

Figure 3. Advanced breeding: Faster product development tools, capability and capacity enable successful delivery as never before.

In many cases, known molecular markers are for disease resistance. With those markers "built in," breeders can focus their efforts on aspects of quality—size, shape, color, taste—that have appeal in the marketplace. With respect to new advanced technologies, momentum is driven by the ability to identify and fine map markers and introgress them rapidly (Figure 4). Seed chipping[2] is proving to be a major driver as it simplifies breeding.

[2]Designed by our engineering colleagues at Monsanto, chipping allows us to determine the genetics of a seed without destroying it.

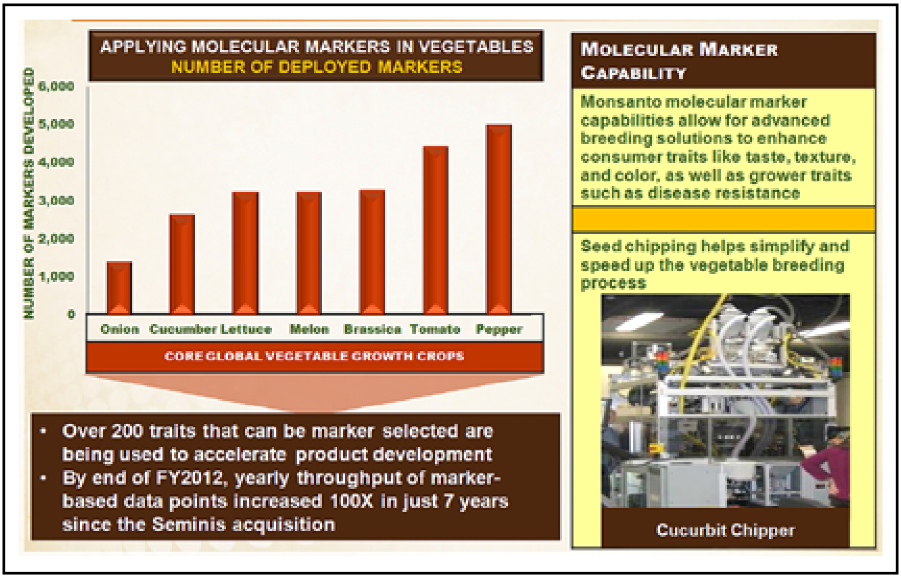

Figure 4. In vegetables, advanced breeding capability accelerates new product development and growth opportunities.

We have identified thousands of markers in vegetable crops (Figure 4). Yearly throughput of marker-based data points has increased 100-fold since our acquisition of Seminis in 2005. Similar acceleration is occurring across the industry, not just within Monsanto.

Phytophthora in Pepper

Of course, it does little good to have a lot of whiz-bang technology if it fails to provide value to growers. *Phytophthora* is a major disease of peppers globally, and we have applied marker-assisted breeding to improve resistance. The source of resistance can be incorporated into other pepper types (Figure 5).

Once the donor source of resistance is identified, the marker for the trait can be identified and introgressed into any number of plant types: jalapeños in Mexico, blocky peppers in the United States, chili peppers in India, *etc*. Field evaluations visually demonstrate significant improvements in resistance of manipulated peppers to *Phytophthora* (Figure 5). However, this is only part of the story. It is essential that the disease-resistant pepper retains the characteristics—heat level, taste, color, shape and size—that growers and consumers expect.

Downy Mildew in Cucumber

Another example is resistance to downy mildew, a major disease of cucumbers. By introgression, we have conferred resistance and commercialized American slicer cucumber varieties in the United States (Figure 6). With the same technology, we will commercialize Beit Alpha cucumbers for the Middle East market, even though these are totally different kinds of cucumbers.

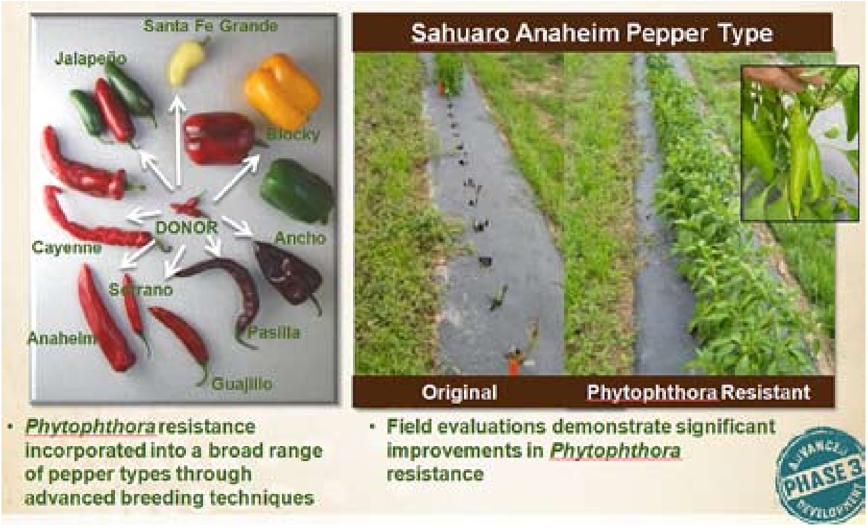

Figure 5. Broadly applying marker-assisted breeding to improve resistance to *Phytophthora* in peppers.

The benefits of technologies that provide fungal resistance are analogous to those that provide insect resistance, Bollgard® and Yieldgard®, in terms of conserving yields and lowering input costs, in this case by reducing need for fungicide applications. Also, there is a systems advantage in achieving less damage from disease by exploiting the plant's genetics.

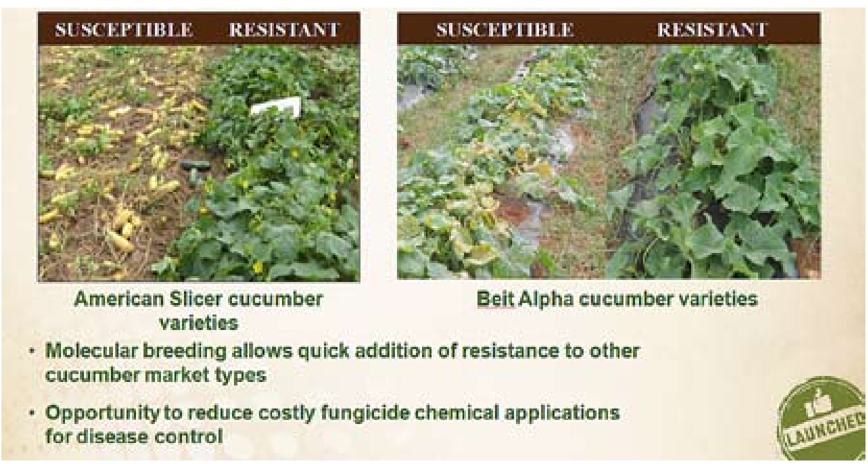

Figure 6. Resistance to downy mildew would improve grower returns in multiple varieties of slicing cucumbers.

BioDIRECT

Ag Biologicals are being more widely used in vegetable crops than in the large-acreage row crops, corn, soybean and cotton. They are particularly advantageous when used in protected culture, *i.e.* within net houses, plastic houses, or glass houses, in which finer environmental control is possible, allowing the biologicals to be used more effectively.

DNA-sequence-based information is available to identify pest targets and to provide active agents that knock out those targets. The pest may be a weed, insect or a pathogen—a virus or a fungus—and the ag biological shuts down a key pathway and controls the pest or pathogen (Figure 7). We heard from Neal Carter and Haven Baker about gene silencing and, basically, what it entails. This approach is in the early stages of development, and a lot of work is aimed in this direction globally.

Figure 8 shows examples with lab trials with pepper and tomato; non-transgenic BioDirect technology clearly provides protection in plants infected with viruses.

We believe that this approach will fuel a resurgence in the use of biologicals and drive the ability to make them even more beneficial than they are already. And we're not alone. Several major agricultural companies are investing in this sector; clearly, it's something that people are excited about. The more we understand at the molecular level, the more we can target specific processes to shut down—to control pathogens and pests—the more advantages we will extract from biological control methods and the more products will be launched in that sector.

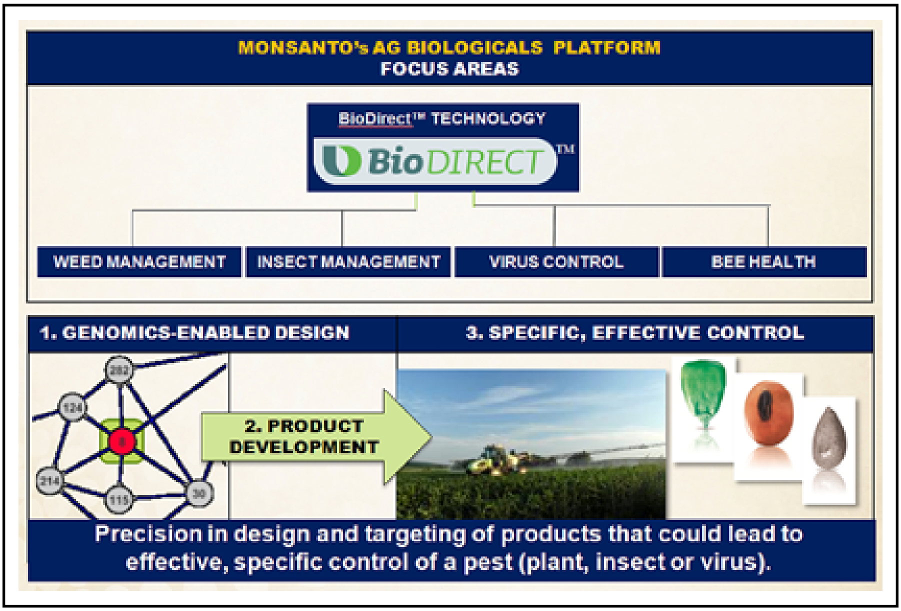

Figure 7. Ag biological: A new class of agricultural biological with the potential to deliver effective crop protection.

I want to stress that as we think about biotechnology in vegetables, there remains a role for "classic" transgenic technologies. And we, and other companies, have some such products in the marketplace. But we also are thinking about this more broadly. The next iteration will be BioDirect and other mechanisms. We are early in the developmental process, but feel that it will help us make strides in the vegetable sector.

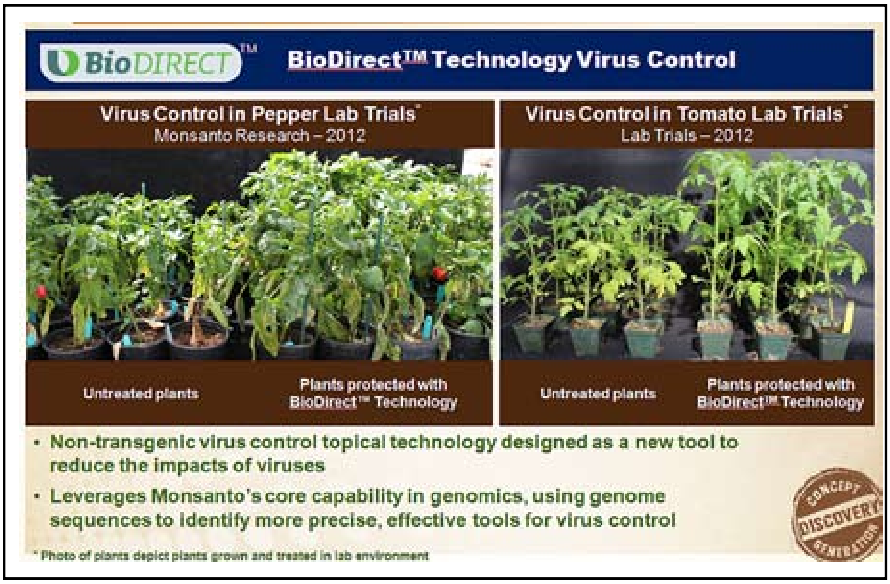

Figure 8. Initial testing indicates that BioDIRECT™ technology could reduce virus-disease symptoms.

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JOHN PURCELL is vice president for technology development for Monsanto Vegetables and serves on Monsanto's vegetable leadership team. In this role, he heads a global effort responsible for supporting the commercialization of vegetable seed products in diverse markets. He is also a senior technology fellow at Monsanto.

Previously, he served on Monsanto's technology leadership team, in which capacity he oversaw a portfolio of technologies and products in the pipeline that bring increasing value to the cotton industry globally. Prior to that role, he held numerous positions in Monsanto's technology organization. He headed a research site in Mystic, Connecticut, and led a research program in Cambridge, UK, focusing on corn and wheat, respectively. Dr. Purcell spent more than 10 years at Monsanto's biotechnology R&D center in St. Louis, where he held jobs of increasing responsibility in the biotechnology research organization. For several years, he headed Monsanto's insect-control program. His role was later expanded to include all plant-protection research including insect, fungal and nematode pests.

Prior to joining Monsanto, he was a postdoctoral researcher at the US Department of Agriculture. His PhD was granted from the University of Massachusetts at Amherst in molecular and cellular biology with an emphasis on insect biochemistry. He is an inventor on several patents and an author of numerous scientific papers, reviews and book chapters.